APPENDIX H: INTERPOLATION OF UTILITY AND ENVIRONMENTAL RESULTS FROM NEMS-BRS OUTPUT

The effects of proposed central air conditioner and heat pump energy-efficiency standards on the electricity and gas industries were analyzed using a variant of U.S. DOE/EIA's National Energy Modeling System (NEMS) called NEMS-BRS, together with some exogenous calculations.[a] Because the relative size of the energy savings being implemented in NEMS-BRS is too small to be seen in the context of the whole electricity and gas utility sector, NEMS-BRS is not used directly. Rather, exploratory runs are conducted to estimate marginal effects, which are then used to calculate the small effects due to each proposed trial standard level.

To run a simulation in NEMS-BRS, the Residential Demand Module central air conditioner and heat pump load is reduced annually according to the energy savings estimated by the National Energy Savings model (see Chapter 7) for each standard level. These electricity energy savings increase over time and differences in usage among U.S. census divisions come from data derived from the Residential Energy Consumption Survey (RECS).[1]

The magnitude of the energy decrement that would be required for NEMS-BRS to produce stable results safely out of the range of numerical noise is greater than even the most stringent standard under consideration. Therefore, it has been necessary, in both the utility and environmental analyses, to estimate results in the range of the standard levels effects using interpolation. Interpolated values are derived from a series of higher decrement simulations based on the standard levels. The actual annual savings attributed to each standard level are compared between standard levels, and those with similar energy savings patterns over time are grouped together. One set of simulations is run for each of the savings groups. The standard levels for the central air conditioner and heat pump analysis were divided into four groups:

Standard Level 1: modeled independently
Standard Level 3: used to model Standard Level 2
Standard Level 4: modeled independently
Standard Level 5: modeled independently

To preserve the pattern of energy savings over time for a trial standard level, savings in each year are multiplied by the same factor. This factor varies for each standard because the magnitude of the savings changes. An appropriate set of multipliers were chosen to augment the savings to a magnitude that produces credible results. Using professional judgement, sets of three multipliers

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[a] For more information on NEMS, please refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000.* DOE/EIA-0581(2000), March 2000. DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because our analysis entails some minor code modifications and the model is run under policy scenarios that are variations on DOE/EIA assumptions, the name NEMS-BRS refers to the model as used here (BRS is DOE's Building Research and Standards office, under whose aegis this work has been performed).

were selected for each of the four patterns as shown in Table H.1.

Table H.1 Set of Multipliers for Each Standard Level Pattern

Standard Level 1	5.25, 6.80, 7.64
Standard Level 3	2.77, 3.59, 4.03
Standard Level 4	2.18, 2.82, 3.17
Standard Level 5	1.18, 1.53, 1.71

The output for electricity generation and capacity by fuel type for each of the iterations (e.g., 6, 8, and 10 times the standard level) is then regressed, with the y-intercept forced through the origin, and the actual standard level forecast is interpolated along this regression line. The linear regression is forced through the origin because a zero change must be the case with no standard in place and because the target points of interpolation are close to the origin (i.e., at low energy decrements). Other trial standard levels within the same group are interpolated along this regression line by substituting the x-value in the regression equation with the ratio of energy savings between standard levels in the peak energy savings year.

Figure H.1a shows an example of the interpolation approach for a central air conditioner and heat pump trial standard level X1. The magnitude of the energy savings multiplier is plotted on the x-axis against the reduction in coal installed generating capacity for each reported year, as shown by the various plotted lines. In general, results for the various NEMS-BRS runs are reasonably stable and linear, with the noisy behavior appearing below the first multiplier of the trial standard level savings decrement.

Figure H.1b shows a close-up of the interpolated points for trial standard level X2 from standard X1. The heavy horizontal lines illustrate the calculated values for the difference in coal capacity in 2020. These regressions appear stable, so estimating results via interpolation toward zero seems justified. A similar approach was used to find the drop in installed generating capacity from other fuels and in generation for each fuel type in each reported year.

The estimated reduction in total fuel generation that we report at each trial standard level as determined by interpolation is then used to determine emissions savings. First, annual marginal emissions rates are calculated for each of the simulations in a savings group, based on the actual output from NEMS-BRS. Marginal emissions rates incorporate both effects of the standards—the emissions saved by the reduction in total generation and the slight change in the emissions characteristics of the whole power sector that result from the slight change in dispatch and capacity expansion plan. The net effect on the entire system is very small and, typically, the overall effect on emissions can be fully attributed to the decremental generation. The annual marginal emissions rates at the trial standard level are then extrapolated from these rates (at multipliers of the trial standard level savings) by taking a simple average.

Figure H.2 shows an example of the extrapolation for NO_x emissions rates for standard level X1. In this case, marginal rates for NO_x emissions are shown for each year. As is evident in the figure, more stable results are produced at higher levels of demand decrement. At lower decrement levels (i.e., both on the left-hand side of the figure and in years with small standards impacts), the emissions rate is quite variable. The dashed plots (years 2003 - 2010) show the earlier years of the imposed standard—those in which the decrements to demand are smallest (not shown here). In most cases, these curves are so close to flat that regression of the higher decrement simulation points produces a curve very close to the simple average of values. The constant emissions rates at higher decrement levels are therefore assumed to hold in the range of small decrements commensurate with the various standard levels, and the implied marginal emissions rates are used to estimate emissions reductions. Total emissions savings in each year are the product of the annual marginal emissions rate and the reduction in thermal generation for that year (as calculated by the interpolation method described above). Marginal emissions rates for all years are derived by averaging the marginal rates of the three highest decrement levels (e.g., 2, 4, and 6 times the standard). Experience has shown that stable marginal emissions factors possess a linear trend over time.

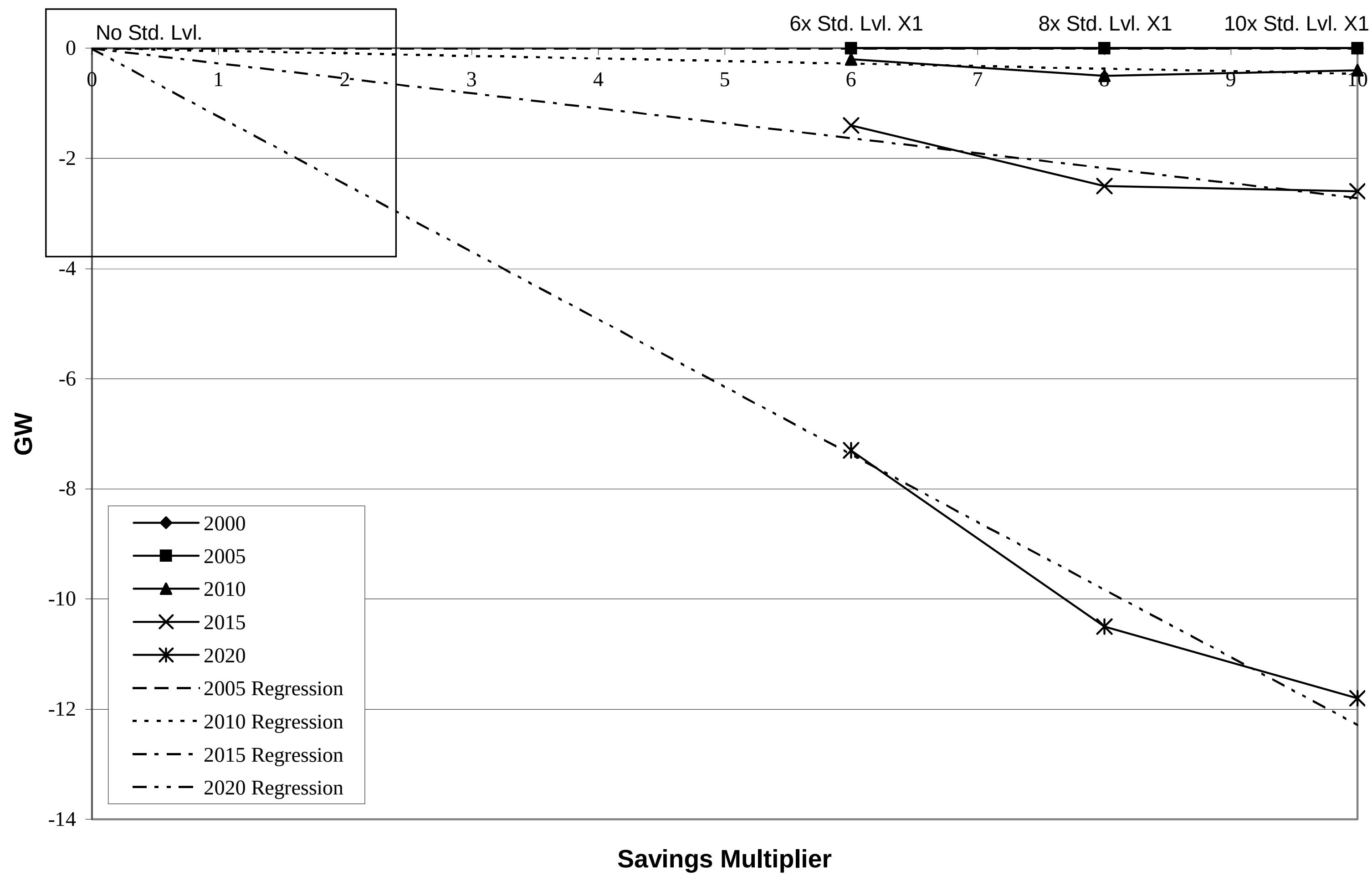

Figure H.1a An Example of the Interpolation of a Trial Standard Level: Difference in Coal Capacity

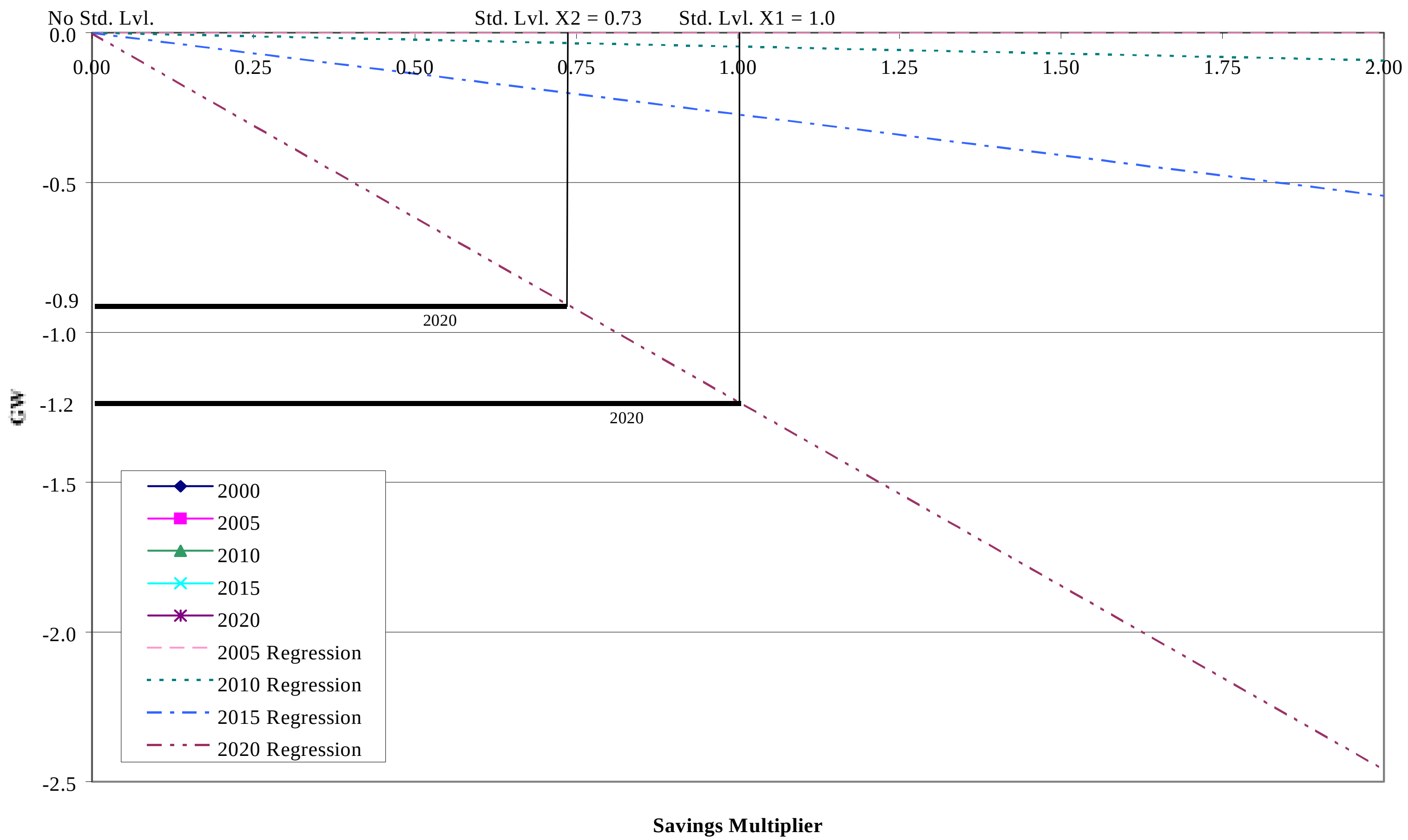

Figure H.1b Close-Up of the Interpolation of Trial Standard Level X2 from X1

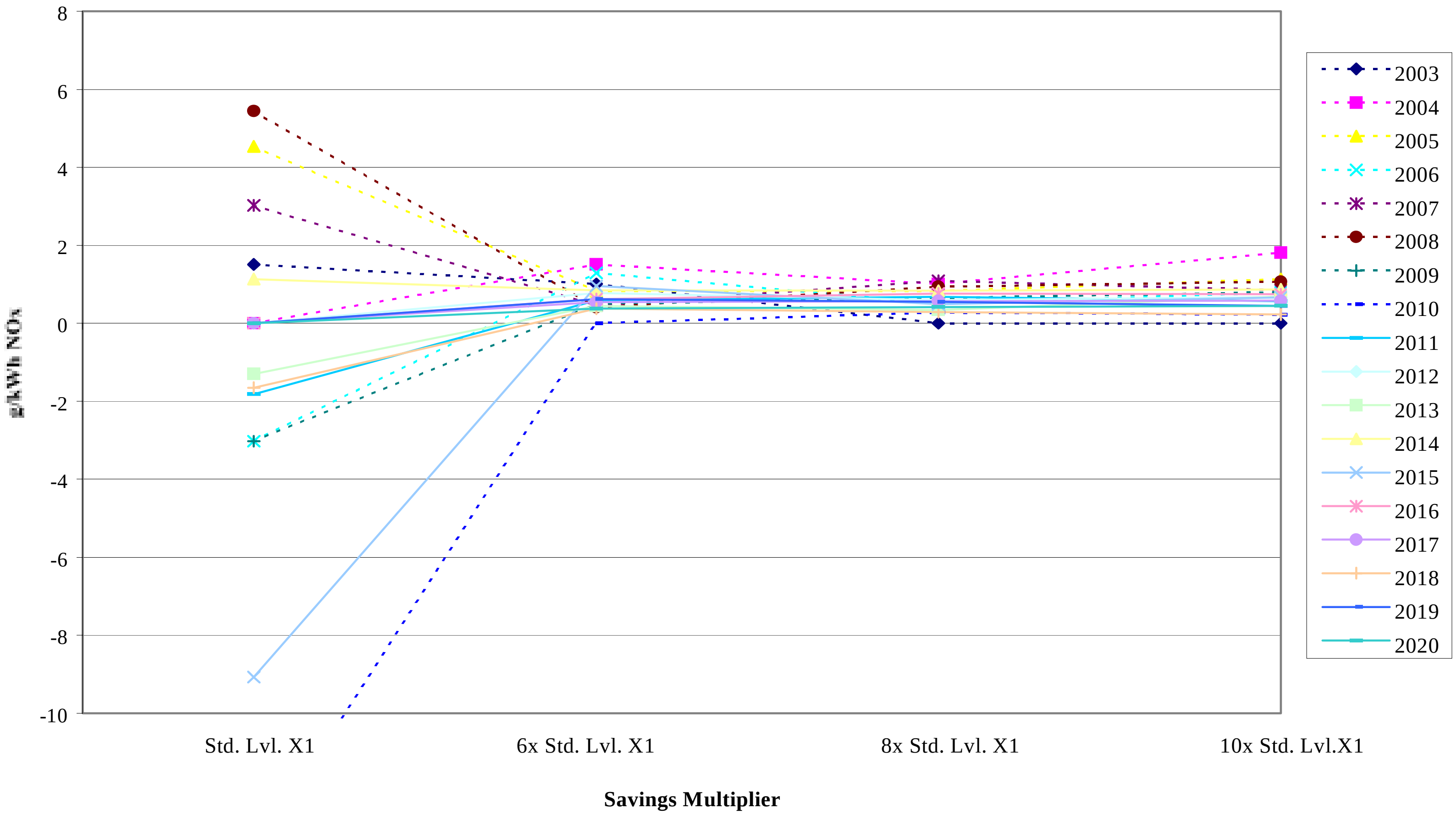

Figure H.2 Example of Trial Standard Level X1: Marginal NO_x Emissions

REFERENCES

1. U.S. Department of Energy-Energy Information Administration, *A Look at Residential Energy Consumption in 1997*, 1999. Washington, DC. Report No. DOE/EIA-0632(97). EIA website: <http://www.eia.doe.gov/pub/pdf/consumption/063297.pdf>